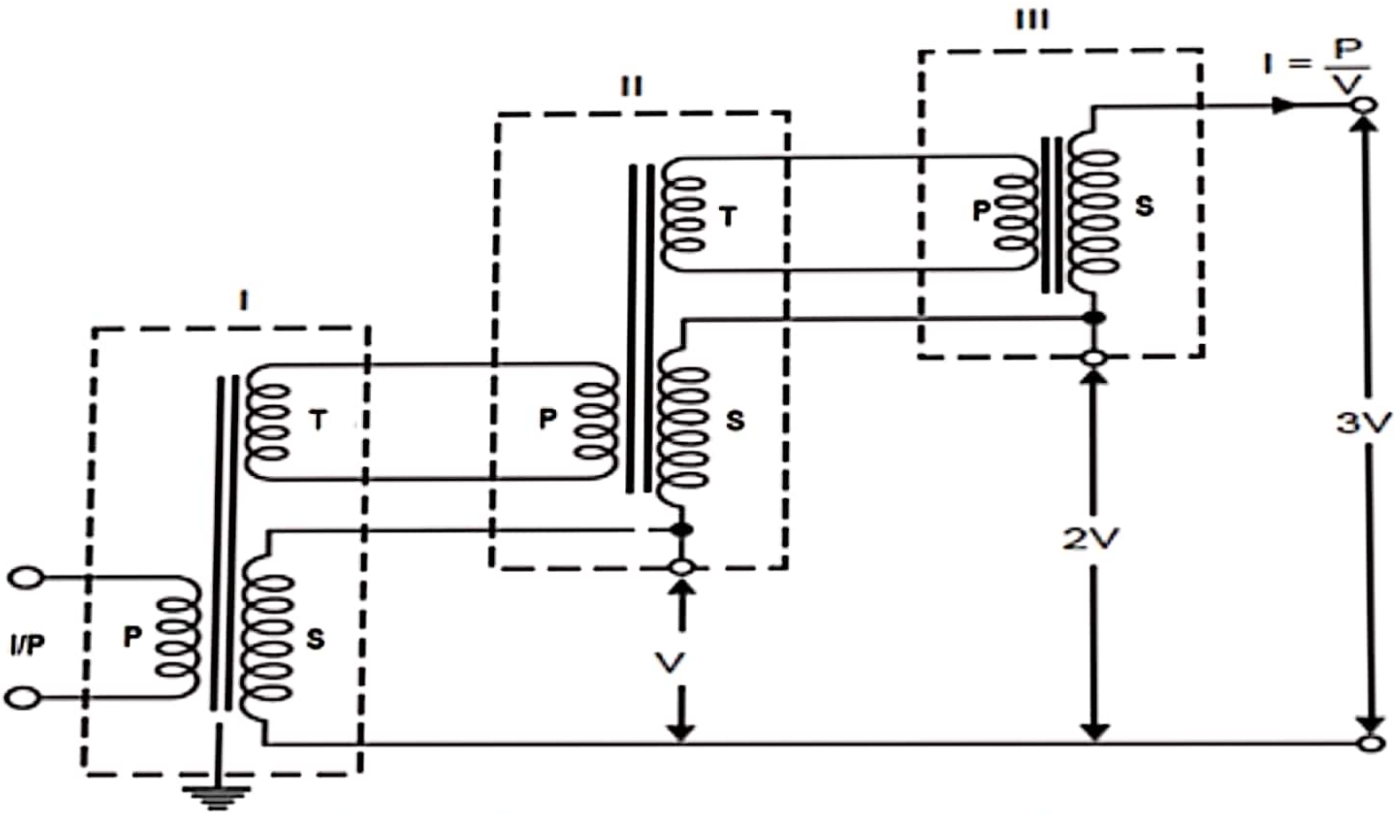
Design considerations in generating high a.c. voltages:

- ✓ Test voltages less than 350 kV can be obtained using single transformer having internal impedance less than 5%.
- ✓ The transformer should be capable of carrying the s.c. current for 1 minutes or more.
- ✓ Apart from main windings, transformer is equipped with meter winding to measure output voltage.
- ✓ For higher voltage requirements, single transformer become too bulky for transportation and installation. The cost of insulation rises.

CASCADED TRANSFORMER



Basic 3 stage cascaded transformer

Cascade Transformer

V_1 - Input voltage

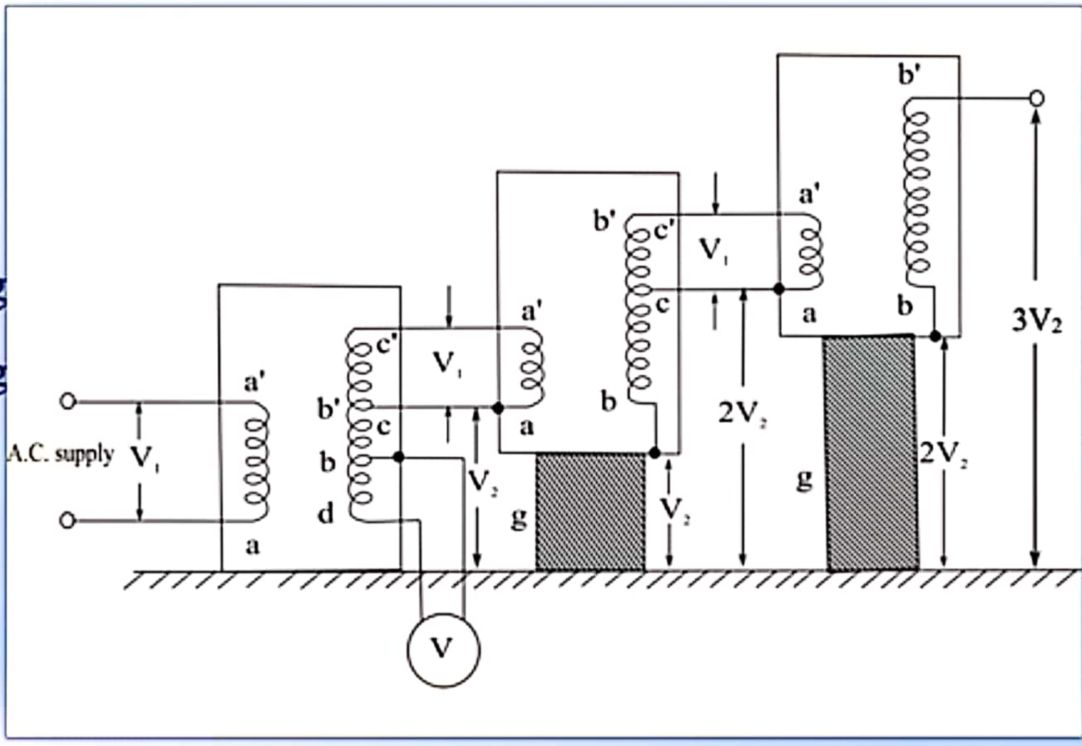
V_2 - Output voltage

aa'- LV primary winding

bb'-HV secondary winding

cc'- Excitation winding

bd - Meter winding (200 to 500 V)



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Construction and working :

1. The primary of the first stage transformer is connected to a low voltage supply.
2. The tertiary winding on the secondary side of first stage has the same number of turns as the primary winding, and feeds the primary of the second stage transformer.
3. The secondary winding of the second stage transformer is connected in series with the secondary winding of the first stage transformer so that a voltage of 2V is available across secondary of second stage transformer and ground.
4. Similarly, the stage-III transformer is connected in series with the second stage transformer.

Construction and working :

5. The tank of stage-I transformer is earthed. The tanks of stage-II and stage-III transformers have potentials of V and 2V, respectively above earth.
6. The tanks of stage-II and stage-III transformers must be insulated from the earth with suitable solid insulation.
7. Through h.t. bushings, the leads from the tertiary winding and the h.v. winding are brought out to be connected to the next stage transformer.
8. Transformer rated with 1 MVA and 1MV are now a days available with charging currents lying in the range of few milliamperes for short time rating for duration of 10-15 minutes.

Advantages:

1. Multiple small transformer units makes transportation and installation easier.
2. Lower cost due to use of smaller units which require moderate insulation.

Limitation:

1. Overall transformer circuit impedance of two stages is 3 - 4 times and for three stage its is 8 - 9 times that of individual transformer, hence low impedance transformers must be used.
2. The primaries of lower stage transformers are loaded more as compared with the upper stages.

Summary:

1. High a.c. voltages can be obtained using single transformers only for voltages upto 350 kV.
2. For higher voltages the cost and weight of single transformer is large.
3. Cascade connected transformer offers several advantages and special construction of tertiary winding is needed.
4. Testing of H.V. apparatus or insulation always involve supplying capacitive load with very low power dissipation.

Generation of high a.c. voltage using Resonant transformer

Principle of operation:

- ✓ The transformer reactances and test object capacitance are connected to form a resonant circuit.
- ✓ The resonance condition is achieved at power frequency by using additional variable choke connected on load side.
- ✓ During the resonance condition the voltage across the test object will rise to very large value since transformer winding resistance is very small.

Resonant Transformer

T - Testing transformer

L - Choke

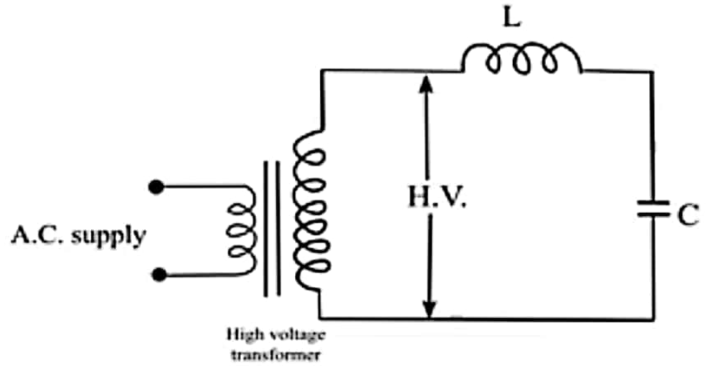
C - Capacitance of test object & transformer bushings

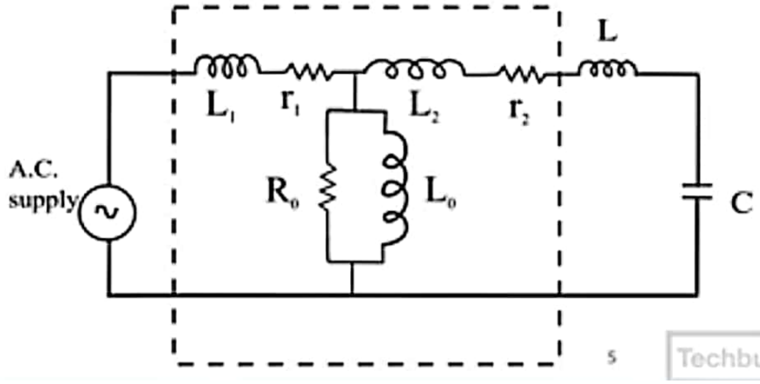
L_0 - Magnetizing inductance

L_1, L_2 - Leakage inductances

r_1, r_2 - Winding resistances

R_0 - Core loss resistance





Construction and working :

1. The equivalent circuit of a high voltage testing transformer is shown in diagram with equivalent shunt capacitance of transformer bushings of H.V. terminal and test object.
2. At power frequency a series resonance is achieved which causes a very large current to flow through the test object, limited only by resistance of transformer windings.
3. The magnitude of voltage across capacitance or test object will be $V_c = \dfrac{V}{\omega CR}$, where R is total resistance in the circuit.
4. The Q-factor of the circuit is $\dfrac{X_c}{R} = \dfrac{1}{\omega CR}$.

Construction and working :

5. The magnitude of voltage multiplication across the test object due to resonance condition is given by the Q-factor.
6. Input voltage required for excitation is reduced by a factor of (1/Q) and also the output kVA required is also reduced by the same factor.

Applications (Large current output):

1. Cable testing
2. Dielectric loss measurement
3. Partial discharge measurement

Advantages:

1. Output is pure sine wave.
2. Power requirement is very less (5-10%) of total kVA.
3. No high power arcing and heavy current surges occur when the test object fails as resonance ceases.
4. Cascading can be done to achieve very high output voltages.
5. Simple and compact test arrangement.
6. No repeated flashovers.

Limitation:

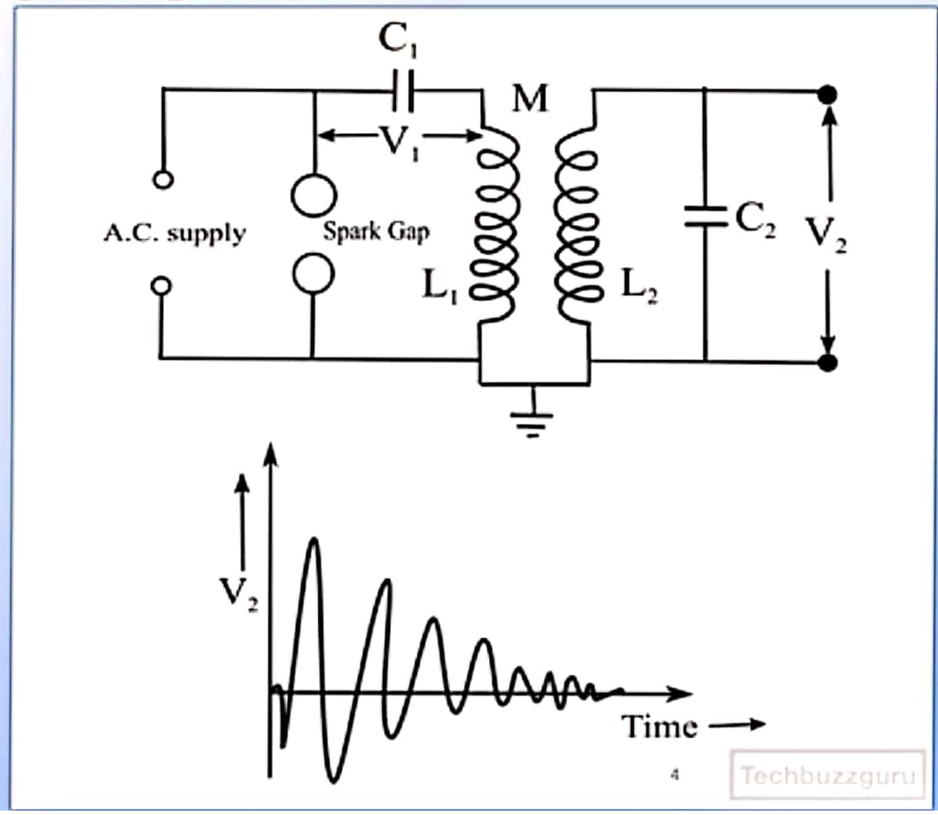
A variable choke is required that can withstand full test voltage and full current rating.

Summary:

1. A resonant transformer circuit produces very high a.c. voltage.
2. The circuit is very simple and compact.
3. This method is useful for large current output application.
4. The kVA output requirement is very low.

High frequency a.c. high voltage using Tesla coil:

1. Spark gap
2. Air core, oil immersed transformer
3. Condensors C_1 and C_2
4. Output Voltage
5. Output waveform



Circuit operation :

1. High frequency, high voltages are required for rectifier d.c. power supplies and testing applications.
2. The most commonly used high frequency resonant transformer is the Tesla coil as shown in equivalent circuit.
3. The primary voltage is 10 kV and secondary may be rated with voltages lying in the range of 500 - 1000 kV.
4. A spark gap connected across the primary is triggered at the desired voltage which induces a high self excitation in the secondary winding.
5. The primary and secondary windings are wound on an insulated former with no core (or air core) and are immersed in oil.

Circuit operation :

6. The transformer windings are tuned to a frequency of 10 - 100 kHz by means of capacitors C_1 and C_2.

Applications:

1. High frequency high voltage rectifier
2. Testing of electrical apparatus for switching surges

Advantages of high frequency transformers:

1. Absence of iron core hence savings in cost and size
2. Gradual voltage buildup, hence no damage due to switching surges
3. Pure sine wave output
4. Uniform distribution of voltage across winding coil

Summary:

1. High frequency a.c. high voltage can be generated using Tesla coil.

2. Transformer has air core and windings are oil immersed. A triggered spark gap is used to generate damped oscillatory voltages.

3. Output voltage of up to 1000 kV can be obtained from 10 kV.

4. High frequency transformer offers several advantages like low cost, small size and pure sine wave output.